

SUBSTITUTE SPECIFICATION

Title: METHOD FOR PRODUCING A TORSION SPRING

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BACKGROUND

Field of the Invention

The present invention relates to methods for producing a torsion spring ^[as a part of] for a micromechanical torsion spring/mass system. More particularly, the invention pertains to the production of a torsion spring ^[which can be produced] from two ^[two] wafers or wafer composites ^[and have a] that possesses low torsional ^[stiffness compared to the] relative to transverse stiffness in the lateral and vertical directions.

Description of the Prior Art

Silicon torsion springs ^[in microstructuring] are known in various design variants ^[already] in microstructuring. For example, C. Kaufman, J. Markert, T. Werner, T. Gessner and W. Dötzel in "Characterization of Material and Structure Defects on Micromechanical Scanners by Means of Frequency Analysis" Proceedings of Micro Materials (1995) p. 443, describe ^[the specialist] relatively long narrow strips, for example, for the

articulated mounting of torsion mirrors. The spring cross section is of trapezoidal shape. ^[the] Springs are formed on opposite wafer edges and ^[are] produced by etching pits from the back surface during structuring of the springs from the front surface. J. Choi, K. Minami and M. Esahi in "Silicon Angular Rate Sensor by Deep Reactive Ion Etching," Proceedings of the International Symposium on Microsystems, Intelligent Materials and Robots (Sendai, Japan, 1995), pages 29 through 32, ^{[Literature reference C2] describe} propose the production of a rectangular torsion cross section, in particular for suspending a tuning fork resonator, with a relatively high aspect ratio (height:width ratio ≥ 4) by deep RIE ^[being proposed as the production method] (reactive ion etching). The two torsion spring cross sections have the disadvantage ^[these] of ^[also being sensitive] sensitivity to ^[drawbacks] transverse stresses. The spring cross-section produced by ^[using] the first method is particularly sensitive to vertical bending, while the spring cross section produced ^[using] by the second method is particularly sensitive to lateral bending.

German patent document DE 28 18 106 A1 discloses a torsion spring ^[which, on account] of a cross-shaped cross-section that has ^[a] low torsional ^[a] ^[the] rigidity compared to transverse rigidity in the lateral and vertical directions. A tube for a sensor that also acts as a torsion spring is disclosed in the Journal

of Microelectromechanical Systems, Vol. 6, No. 2 (June

^[discloses a tube of a sensor which also acts as a torsion spring]
1997) at pages 119 through 125. [^]The [^]tube is produced

^[This]
using the Coriolis principle, by turning wafers, placing
them against one another in a mirror-symmetrical manner
and bonding them, in each case with a trench formed
therein.

^[As] ^[example of an]

[^]In a further [^]application of such torsion

springs, rotary mirrors and micromechanical rotation rate

sensors are ^[pointed out] [^]mentioned in International patent ^[application] [^]publication

^[this]
WO 96/38710. In particular, Figure 8 of [^]that document

^[shows] [^]illustrates a double-layer vibratory structure ^[which] [^]that is

^[means of] [^]held in a frame by a cross-shaped spring joint formed from
the wafer layers. This cross-shaped spring joint, which

is formed from a total of four individual spring elements,

^[the desired] [^]improves stiffness in the wafer levels, ^[to which] [^]a fact ^[reference is] [^]referred to

^[above-mentioned WO document] [^]in the [^]patent publication. For a vibratory structure of

^[of which are] [^]this type, [^]in which the vibrators, arranged in plate form
above one another, form a micromechanical rotation rate

sensor based on the Coriolis principle, ^[however] [^]it is desirable to

^[said] [^]optimize the cross-shaped spring joint ^[specifically] [^]in such a way that

transverse stiffness ^[compared] [^]relative to torsional stiffness ^[which] [^]is as

high as possible in the direction of the wafer planes and

perpendicular thereto ^[the] [^](i.e. in the lateral and vertical

^[results] [^]directions)

SUMMARY AND OBJECTS OF THE INVENTION

It is therefore the object of the invention to provide a method for producing an optimized torsion spring for a micromechanical torsion spring/mass system.

5 The invention addresses the above object by providing a method for producing a torsion spring with low torsional compared to transverse stiffness in the lateral and vertical directions, as part of a micromechanical torsion spring/mass system from two wafers or wafer
10 composites. Such method is begun by producing a spring extending over the entire thickness of the wafer or wafer composite by anisotropic wet chemical etching. The spring has a V-shaped cross section that is laterally delimited by [111] planes on at least one side edge region of each
15 wafer or wafer composite.

The method then continues by rotating the two wafers or wafer composites through 180°. Finally, the two wafers or wafer composites are joined to one another, for
20 example by bonding, while oriented with respect to one another in a mirror-image fashion so that an overall x-shaped torsion of the two V-shaped spring cross sections.

The foregoing and other features of the

invention will become further apparent from the detailed description that follows. Such description is accompanied by a set of drawing figures. Numerals of the drawing figures, corresponding to those of the written description, point to the features of the invention with like numerals referring to like features throughout both the written description and the drawing figures.

[The invention is explained in more detail below with reference to two exemplary embodiments, in which:]

BRIEF DESCRIPTION OF THE DRAWINGS

[shows]

Figure 1 illustrates a first method in accordance with the invention for producing a torsion spring with an X-shaped cross-section [from two wafers]; and

[shows]

Figure 2 illustrates a second method in accordance with the invention for producing a torsion spring with an X-shaped cross-section. [modified procedure]

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figure 1 illustrates a first method in accordance with the invention for producing a torsion spring with an X-shaped cross section from two wafers. In [the case of] Figure 1, the starting point for the method is two identical wafers, while in Figure 2, which illustrates a second method in accordance with the invention, the

[production]
starting point for the method is two wafer layer
composites, [which are] [from one another] separated or electrically insulated from one
another along their common surface plane by an insulating
[having a layer thickness of, for example, up to 4 μm]
layer 1. Strip-shaped etching masks 2 are applied in the
5 lateral edge region of the wafers or [et] the wafer composites.

[Then] A spring 3 with a V-shaped cross section, which is
laterally delimited by [111] planes, is then produced in
the edge region of each wafer or wafer composite by
anisotropic, wet-chemical etching. [Then,]
10 wafer composites which have been prepared with a V-shaped
spring in this way are rotated through 180° with respect
to one another and are then joined [bonded] to one another oriented
mirror image symmetrically with respect to one another.
The joint process may be employed [in particular by silicon direct bonding] so that the desired
15 transversely rigid torsion spring of [which is] [is] X-shaped cross
[is] section is formed as a suspension element for a uniform
torsion spring/mass system structure.

If the invention is used in combination with the
production of micromechanical rotation rate sensors, the
20 basis used [in order] (to be able to release different excitation
potentials or reset signals, on the one hand, and feed and
readout potentials, on the other hand, to the outside) is
preferably a two-layered wafer composite [in] [one] for each of the
plate-type oscillators. [In order, for example,]
To be able to supply or remove

four different electrical potentials by the crossed
[of the torsion springs produced using the method according to the invention]
springs, it is advantageous for an insulating oxide to be
formed on the surface of at least one of the wafers or the
wafer composite ^[on that surface which] that faces the other wafer or the other
wafer composite during bonding.

The X-shaped, integrally joined torsion spring
cross section ^[which is] ^[as a result of] formed by the method increases the ratio of
transverse stiffness to torsional stiffness ^[compared] as opposed to
a rectangular cross section ^[, but also] and also as compared to
individual crossed spring elements, as ^[are shown] described in WO
96/38710, by more than two orders of magnitude. ^[the above mentioned]

A particular advantage of the method ^[according to] of the
invention resides in ^[the] its simple technology. ^[since] The torsion
spring is not ^[influenced] affected by time-dependent etching
processes. ^[as a result] ^[so that overall] ^[the] ^[which] Only one etching step takes place that is
critical in terms of time duration in the overall assembly
of the two V-shaped springs. ^[takes place]

The dimensional accuracy of the torsion spring,
the masks of which obviously include long, narrow
structures, is dependent, inter alia, ^[on] upon precise
matching ^[between] of the crystal direction [110] ^[and the respective] to mask
orientation. ^[that this is achieved in the invention, for] To insure precise orientation of the wafers

with respect to one another and/or of wafers with respect to masks, the setting reference for the joint process, in particular silicon direct bonding, and the lithography is oriented in the $[[110]]$ crystal direction using suitable chemical, plasma-chemical and/or mechanical means. This orientation may, for example, be affected by initially providing the wafers with an etching mask which is produced parallel to the ground bevel of a mask edge. ^[then] The wafers are then anisotropically overetched using this mask, ^[with the result that] resulting in the formation of ^[is formed] a new reference bevel, which then serves as an optical or mechanical (preferably gravity-assisted adjustment) reference for the joint process and the lithography, i.e. the mask orientation.

While this invention has been described with reference to its presently-preferred embodiment, it is not limited thereto. Rather, the invention is limited only insofar as it is described by the following set of patent claims and includes within its scope all equivalents thereof.